S/X Open-Loop Receiver

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An operational DSN S-band receiver having two independent channels was modified to provide capability for coherent reception at S- and X-bands simultaneously. Coherence at both bands was accomplished by using a base-frequency multiplier which was common to both the S- and X-band local oscillator multiplier chains.

I. Introduction

In order to meet the occultation experiment requirements for coherent downlink phase information from a spacecraft at S- and X-bands, the DSN S-band open-loop receiver at DSS 14 was modified. Presently, the open-loop receiver has two independent S-band channels. Channel 2 was modified to receive at X-band. This modification was made without disturbing either S-band link. To meet the requirements, Channel 2 was preceded by an X- to S-band down-converter. Switching networks were added so that in the new S/X-band mode, occultation experiments can be carried out simultaneously at S- and X-bands. Coherence requirements for the two downlink signals were met by utilizing a common base-frequency for both the S- and X-band local oscillator (LO) chains. Whenever possible, components and modules already designed or in DSN use were employed in order to minimize replacement spares and cost.

II. Physical Description

The S/X open-loop receiver consists basically of two assemblies mounted in the tricone at DSS 14. One assembly, called the S/X open-loop receiver panel (panel), contains the times sixteen (×16) base-frequency multiplier and other lower-frequency multipliers to generate the LO signal for the existing S-band mixers (see Fig. 1). The panel, mounted in receiver cabinet 9, is 43 cm wide, 51 cm long, and 9 cm high.

The other assembly, S/X open-loop receiver box (box), consists of a weather-resistant enclosure containing the components required in the generation and conversion of the higher X-band frequency (Fig. 2). The Box measures approximately 41 × 51 × 15 cm deep.

III. Development

Figure 3 shows a block diagram of the S/X open-loop receiver. Basically, the system consists of two reference frequency sources which drive frequency multiplier chains to supply the LO signals for the existing S-band mixers and the new X-band mixer. The ×16 base-frequency multiplier, which is common to both multiplier chains, has dual outputs. One output provides the drive for the S-band LO chain, while the other provides the drive for the X-band LO chain. Coaxial RF switches select either normal S-band operation or the new S/X-band mode. In the normal S-band mode, the existing S-band LO signals are switched into the existing S-band mixers. In the S/X-band mode, the new coherent S-band LO is switched to the existing Channel 1 S-band mixers, and simultaneously, the X-band LO is switched to the new X-band mixer in Channel 2.

Starting at the upper left in Fig. 3, reference frequency source f_1 drives the dual output ×16 base multiplier. One output of the ×16 multiplier drives a ×3 multiplier, which generates the nominal 2245-MHz LO for the existing S-band mixers. This LO signal is split by a 3-dB hybrid and followed by bandpass filters FL1 and FL2. Switches S1 and S2 are operated simultaneously and, for S/X-band operation, select the new coherent LO generated by the ×16 and ×3 multipliers. For normal S-band operation, S1 and S2 select the existing S-band LO signals. Either set of LOs is applied to the existing S-band mixers in Channels 1 and 2.

The other output from the ×16 base multiplier is used to further develop the LO for the new X-band mixer. At the left in Fig. 3, reference frequency source f_2 drives a ×1/3 frequency multiplier. The output is mixed with the output from the ×16 multiplier. The resultant sum frequency, a nominal 765 MHz, is further multiplied by a ×8 multiplier to provide the 6120-MHz LO drive for the X-band mixer. The LO is processed through bandpass filters and isolators HY2, FL3, HY3, FL4, and HY4 before being applied to the X-band mixer. The X-band downlink signal, nominally at 8415 MHz, comes in through the preselector filter and mixes with the 6120-MHz X-band LO in X-band mixer M1. The resulting difference intermediate frequency at 2295 MHz is amplified by AR1. Switch S3 operates together with switches S1 and S2, and when it is in the S/X-band mode, selects the 2295-MHz S-band IF generated by the X- to S-band mixer. When the switch is in the normal S-band mode, it selects the normal 2295-MHz S-band signal to Channel 2. The signal is then fed to the S-band mixer in Channel 2. The various signal frequencies are shown in the diagram.

Perhaps the most significant area of development dealt with the suppression of spurious signals generated by the 6120-MHz ×8 frequency multiplier in the X-band LO chain.

Intermodulation products are generated in the mixer following the ×8 multiplier due to mixing of harmonics and sidebands of the ×8 multiplier output. Since the S- and X-bands are coherently related, the ×3 sideband at the output of the ×8 multiplier is at the same frequency as the IF from the X-band mixer. In addition, the ×5 and ×11 sidebands mix with the ×8 output also to generate an interference signal at the same frequency. The interference signals could mask the real signals if they were not adequately attenuated. Faced with these possibilities, the best approach was to suppress every harmonic of the ×8 input frequency appearing at the multiplier output except the required LO for the X-band mixer.

Bandpass filters FL3, FL4 and wideband isolators HY2, HY3, HY4 were used for this purpose. Typical microwave filters are of the reflective type, wherein high voltage standing wave ratio (VSWR) is exhibited in the reject band. The addition of an isolator at the input port allows the isolator to absorb the out-of-band reflected signals by an order of about 20 dB per unit. The isolator also helps in creating a better match for the in-band frequencies.

Before one can realize higher orders of suppression, RF leakage must be eliminated or at least minimized. Therefore, special precautions were taken in packaging the ×8 multiplier, isolator HY2, and filter FL3 (Fig. 4). The ×8 multiplier and HY2 were mounted within an RF-shielded enclosure. The input interface of FL3 was mounted flush against one exterior surface of the enclosure, with the input connector protruding into the enclosure through a clearance hole. The two mounting surfaces were machined smooth in order to minimize leakage. With this arrangement, the filter input was virtually RF-isolated from its output. Skin currents at the input were contained within the enclosure. Test results confirmed excellent containment of leakage in the area of the $\times 8$ and FL3.

Before the filtering was added, the interference signal levels were approximately -85 dBm following the X- to S-mixer. With the addition of HY2 and FL3, this level was reduced to -141 dBm, a reduction of 56 dB. A second suppression stage, consisting of HY3 and FL4 was added, and this reduced the spurious levels well below threshold signal levels. Because of reactive coupling between FL4 and the X-band mixer, HY4 was added to insure a better VSWR.

Certain precautionary measures had to be observed when working with these high attenuation levels:

(1) Connectors had to be clean at their mating surfaces. Slight amounts of foreign matter can easily influence test results. In this respect, the smaller connectors, such as SMA, are notorious for generating metal flaking from their threads. Both connector ends should always be examined for cleanliness before mating.

(2) SMA connections easily become loose during the course of testing and development. Best results were obtained when these connections were torqued to about 12.4 g-cm (9 in.-lb) before starting tests.

IV. Discussion

The S/X modification is an R & D type of installation. Work will shortly be under way to provide a permanent unit at DSS 14 which will replace the R&D system. An S/X open-loop receiver will also be provided at DSS 43.

Because of the space limitations in receiver cabinet 9, the present S/X open-loop receiver panel will be reconfigured, possibly by relocating the $\times 1/3$ multiplier-mixer to the box assembly.

Additional trimmer attenuators may be added to further balance the S-band LO signals. A crystal detector monitor will be added to provide control room personnel with an indication of the X-band and LO signal.

The $\times 8$ multiplier will be replaced by a $\times 2$ multiplier, followed by a $\times 4$ multiplier. This change in the $\times 8$ multiplier chain should reduce the levels of undesirable S-band signals appearing at the output of the X-band mixer.

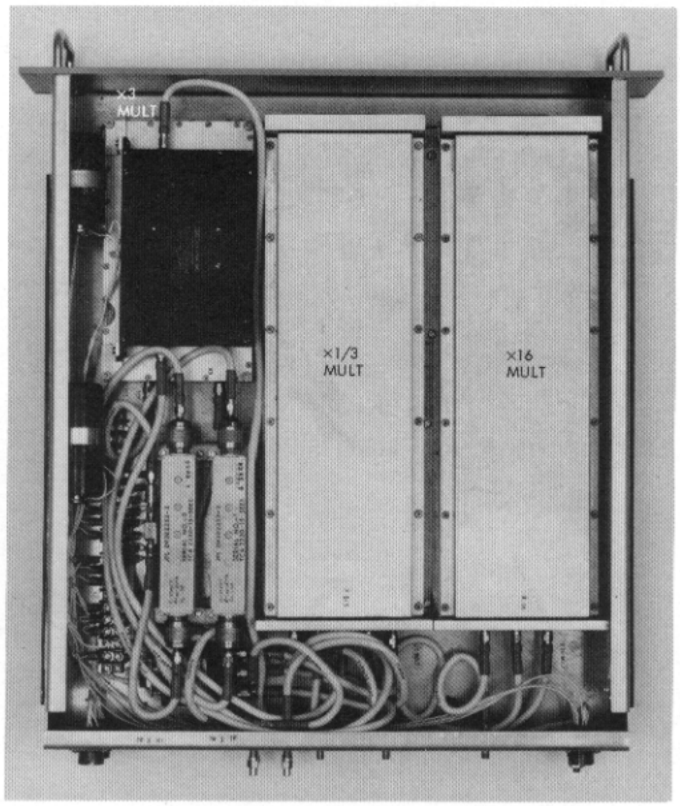

Fig. 1. S/X open-loop receiver panel

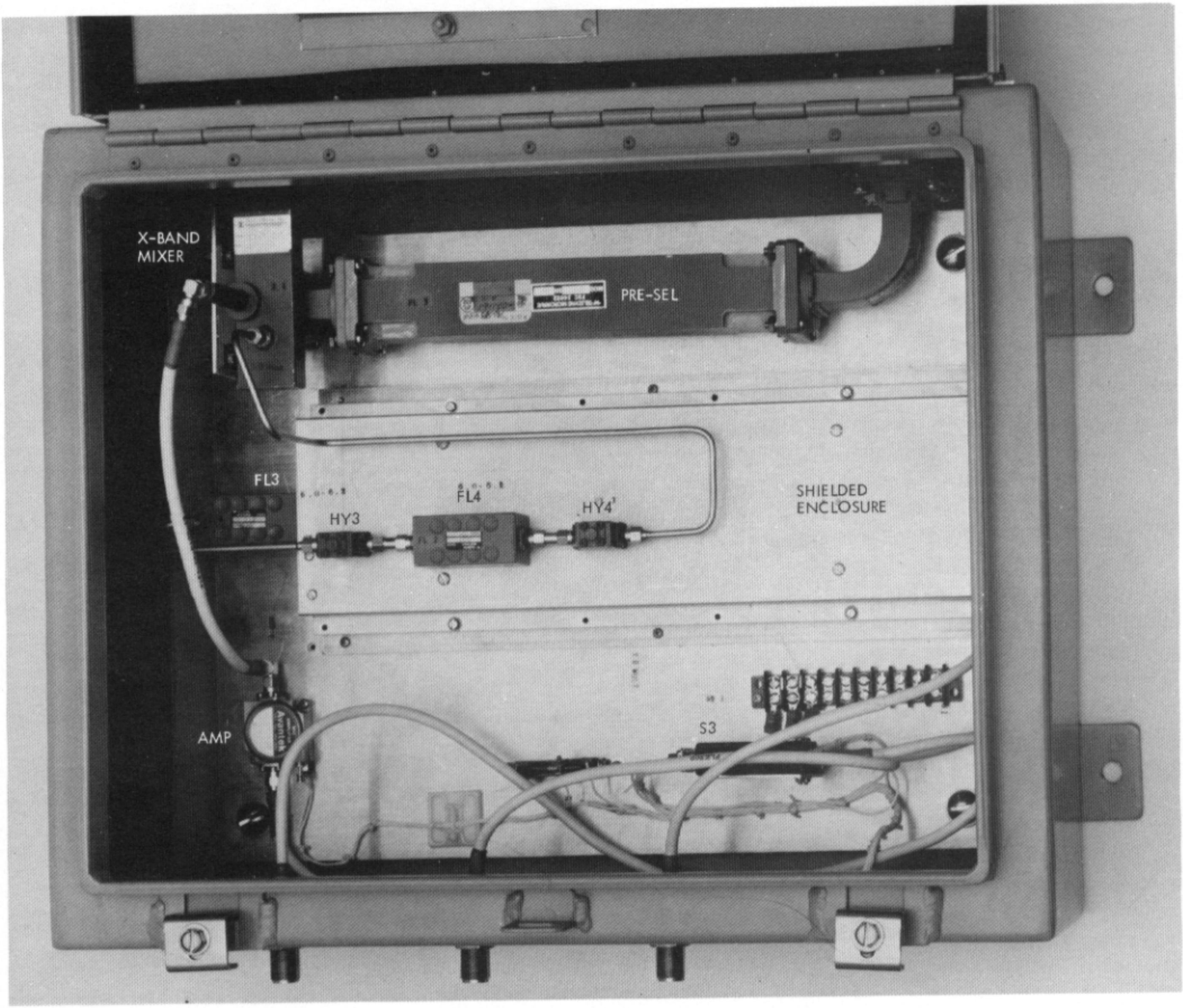

Fig. 2. S/X open-loop receiver box

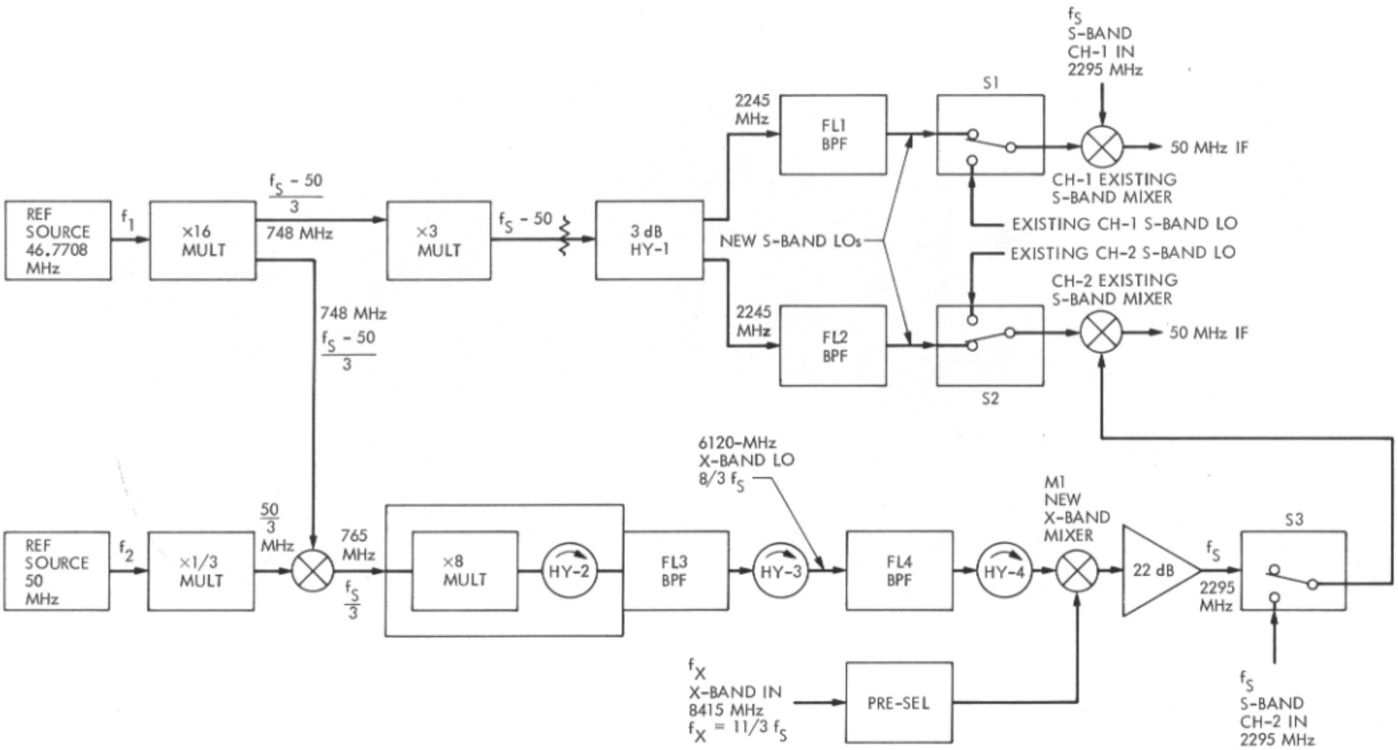

Fig. 3. S/X open-loop receiver (S1, S2, S3 shown in S/X-band mode)

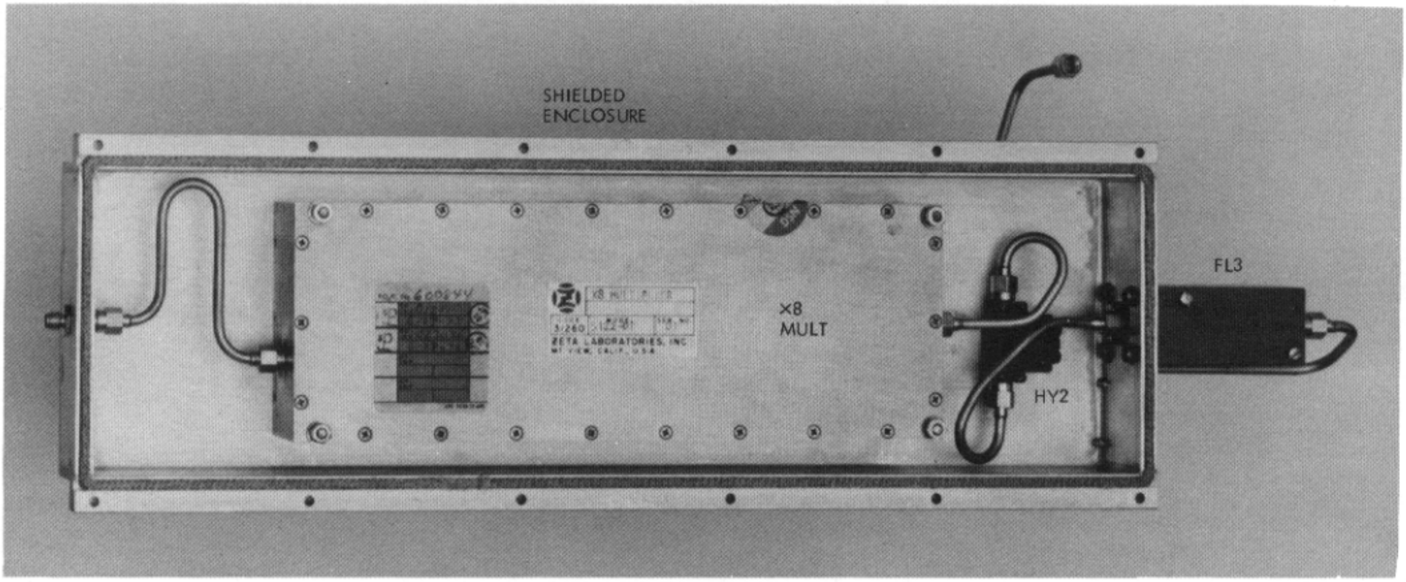

Fig. 4. ×8 multiplier